JC20 Rec'd PCT/PTO 29 MAR 2002

FORM PTO-1390 U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE (REV. 11-2000) **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		**ATTORNEY'S DOCKET NUMBER** 32860-000287/US **U.S. APPLICATION NO. (If known, see 37 CFR 1.5)** 10/089301
INTERNATIONAL APPLICATION NO. PCT/DE00/03424	**INTERNATIONAL FILING DATE** September 29, 2000	**PRIORITY DATE CLAIMED** September 30, 1999

TITLE OF INVENTION
METHOD AND DEVICE FOR LASER DRILLING LAMINATES

APPLICANT(S) FOR DO/EO/US
Hubert DE STEUR; Marcel HEERMAN; Jozef Van PUYMBROECK

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39 (1).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau). WO 01/26434 A1
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is transmitted herewith.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4)
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 20. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98-1449 and International Search Report (PCT/ISA/210) in German with eleven (11) references and a German Translation Aid.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☒ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:

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U.S. APPLICATION NO (if known, see 37 CFR 1 5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
NEW 10/089301	PCT/DE00/03424	32860-000287/US

21. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1,040.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO......... **$710.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)............... **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 0	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	28 - 20 =	8	X **$18.00**	$ 144.00	
Independent Claims	2 - 3 =	0	X **$84.00**	$ 0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)		None	+ **$280.00**	$ 0	

TOTAL OF ABOVE CALCULATIONS =	$ 1,034.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.	$ 0	
SUBTOTAL =	$ 1,034.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐20 ☐30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$ 0	
TOTAL NATIONAL FEE =	$ 1,034.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +	$ 40.00	
TOTAL FEES ENCLOSED =	$ 1,074.00	
	Amount to be: refunded	$
	charged	$

a. ☒ A check in the amount of $ **1,074.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account. No. 08-0750 in the amount of $ to cover the above fees. A triplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 08-0750.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

Send all correspondence to:

Harness, Dickey & Pierce, P.L.C – Customer No. 30596
Post Office Box 8910
Reston, Virginia 20195

Date: MARCH 29, 2002

By [signature]
Donald J. Daley, #34,313

/kna

#4/a

PATENT
32860-000287/US

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicants: Hubert De STEUR; Marcel HEERMAN; Josef Van PUYMBROECK

Int'l App. No.: PCT/DE00/03424

Application No.: **NEW**

Filed: March 29, 2002

For: METHOD AND DEVICE FOR LASER DRILLING LAMINATES

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, DC 20231

March 30, 2002

Sir:

The following preliminary amendments and remarks are respectfully submitted in connection with the above-identified application.

IN THE ABSTRACT

Please replace the Abstract with the attached revised Abstract.

IN THE CLAIMS

Please amend the claims as follows:

1. (Amended) A method for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer including an organic material, comprising:

using a frequency-doubled Nd vanadate laser having the following laser parameters,

pulse width < 40 ns,

pulse frequency ≥ 30 kHz for the metal layer and

≥ 20 kHz for the dielectric layer, and

wavelength = 532 nm.

2. (Amended) The method as claimed in claim 1, wherein a pulse width of < 30 ns is used.

3. (Amended) The method as claimed in claim 1, wherein a focused laser beam with a spot diameter of between 10 μm and 100 μm is used.

4. (Amended) The method as claimed in claim 3, wherein a focused laser beam with a spot diameter of between 20 μm and 40 μm is used.

5. (Amended) The method as claimed in claim 1, wherein additives which have good absorptance for laser beams with a wavelength of 532 nm are admixed with the organic material.

6. (Amended) The method as claimed in claim 5, wherein at least one of an inorganic and an organic pigment, at least one polymer-soluble dye and at least one fibrous filler is used as additive.

7. (Amended) The method as claimed in claim 6, wherein at least one of an inorganic red pigment and an organic red pigment, and a polymer-soluble red dye is used as additive.

8. (Amended) The method as claimed in claim 6, wherein between 0.1% by weight and 50% by weight of pigments are admixed with the organic material.

9. (Amended) The method as claimed in claim 6, wherein between 1% by weight and 2% by weight of pigments are admixed with the organic material.

10. (Amended) The method as claimed in 5, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

11. (Amended) The method as claimed in claim 5, wherein the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

12. (Amended) The method as claimed in claim 5, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

13. (Amended) A device for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer comprising an organic material, comprising:

a frequency-doubled Nd vanadate laser having the following laser parameters,

pulse width	< 40 ns,
pulse frequency	≥ 30 kHz for the metal layer and
≥ 20 kHz for the dielectric layer, and	
wavelength	= 532 nm.

Please add the following new claims:

-- 14. The method as claimed in claim 2, wherein a focused laser beam with a spot diameter of between 10 μm and 100 μm is used.

15. The method as claimed in claim 3, wherein a focused laser beam with a spot diameter of between 20 μm and 40 μm is used.

16. The method as claimed in claim 7, wherein between 0.1% by weight and 50% by weight of pigments are admixed with the organic material.

17. The method as claimed in 6, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

18. The method as claimed in 7, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

19. The method as claimed in 8, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

20. The method as claimed in 9, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

21. The method as claimed in claim 6, wherein the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

22. The method as claimed in claim 7, wherein the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

23. The method as claimed in claim 8, wherein the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

24. The method as claimed in claim 9, wherein the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

25. The method as claimed in claim 6, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

26. The method as claimed in claim 7, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

27. The method as claimed in claim 8, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

28. The method as claimed in claim 9, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation. --

REMARKS

Claims 1-28 are now present in this application, with new claims 14-28 being added by the present Preliminary Amendment. It should be noted that the amendments to original claims 1-13 of the present application are non-narrowing amendments, made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations. For example, amendments have been made to broaden the claims; remove the European phrases "characterized in that" and "characterized by"; remove multiple dependencies in the claims; and to place claims in a more recognizable U.S. form, including the use of the transitional phrase "comprising" as well as the phrase "wherein". Other such non-narrowing amendments include placing apparatus-type claims (setting elements forth in separate paragraphs) and method-type claims (setting forth elements beginning with "-ing" in

separate paragraphs) in a more recognizable U.S. form. Again, all amendments are non-narrowing and have been made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations.

SUBSTITUTE SPECIFICATION

In accordance with 37 C.F.R. §1.125, a substitute specification has been included in lieu of substitute paragraphs in connection with the present Preliminary Amendment. The substitute specification is submitted in clean form, attached hereto, and is accompanied by a marked-up version showing the changes made to the original specification. The changes have been made in an effort to place the specification in better form for U.S. practice. No new matter has been added by these changes to the specification. Further, the substitute specification includes paragraph numbers to facilitate amendment practice as requested by the U.S. Patent and Trademark Office.

CONCLUSION

Accordingly, in view of the above amendments and remarks, an early indication of the allowability of each of claims 1-28 in connection with the present application is earnestly solicited.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Donald J. Daley at the telephone number of the undersigned below.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 08-0750 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

HARNESS, DICKEY & PIERCE, P.L.C

By: ______________________
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DJD:kna

ABSTRACT OF THE DISCLOSURE

A method and device for the laser drilling of laminates includes the use of a frequency-doubled Nd vanadate laser. The laser includes the following parameters: pulse width < 40 ns, pulse frequency ≥ 30 kHz for the metal layer and ≥ 20 kHz for the dielectric layer, and wavelength = 532 nm. Such a laser is used for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer including an organic material.

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~~Description~~

METHOD AND DEVICE FOR LASER DRILLING LAMINATES~~Method and device for the laser drilling of laminates~~

[0001] This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/DE00/03424 which has an International filing date of September 29, 2000, which designated the United States of America, the entire contents of which are hereby incorporated by reference.

Field of the Invention

[0002] The invention generally relates to laser drilling.

Background of the Invention

[0003] It is known from EP-A-0 164 564 to produce blind bores in a laminate comprising the layer sequence metal-dielectric-metal with the aid of an excimer laser. The top metal layer of the laminate is in this case used as a perforated mask, the pattern of perforations in which is transferred photographically and is produced by subsequent etching. The dielectric which is uncovered in the region of the hole of this mask is then removed by the action of the excimer laser until the bottom metal layer is reached and the process of removing material is terminated. The known method is used in particular to produce the required through-contact holes in the form of blind bores during the fabrication of multilayer circuit boards.

[0004] German journal "Feinwerktechnik & Messtechnik 91 (1983) 2, pp. 56-58 has disclosed a similar method for the fabrication of multilayer circuit boards in which the blind bores which are used as through-contacts are produced with the aid of a CO_2 laser. In this case too, the top copper foil is used as a perforated mask, in which the copper is etched away wherever the laser beam is to produce a hole.

[0005] DE-A-197 19 700 has also already disclosed devices for the laser drilling of laminates in which a first laser, having

a wavelength in the range from approximately 266 nm to 1064 nm, is used to drill the metal layers and a second laser, having a wavelength in the range from approximately 1064 nm to 10 600 nm, is used to drill the dielectric layers.

[0006] US-A-5 593 606 has disclosed a method for the laser drilling of laminates in which a single UV laser, the wavelengths of which are below 400 nm and the pulse widths of which are below 100 ns, is used to drill the metal layers and to drill the dielectric layers. Therefore, on the condition that an excimer laser is not used, metal and organic material are drilled using the same UV laser.

[0007] DE-A-198 24 225 has disclosed a further method for the laser drilling of laminates, in which, by way of example, an SHG (second harmonic generation) YAG laser with a wavelength of 532 nm or a THG (third harmonic generation) YAG laser with a wavelength of 355 nm can be used to drill the metal layers and to drill the dielectric layers.

[0008] It can fundamentally be stated that, when UV lasers, i.e. lasers with wavelengths of below 400 nm, are used for the laser drilling of organic materials, photochemical decomposition of the organic materials takes place. Therefore, there is no burning and, on account of the at most extremely low thermal load, there is no delamination when used for laminates. By contrast, when CO_2 lasers are used for the laser drilling of organic materials, thermal decomposition of the organic materials does occur, i.e. burning may occur and there is a risk of delamination in the case of laminates. However, compared to UV lasers, CO_2 lasers can achieve considerably shorter processing times when drilling organic materials.

SUMMARY OF THE INVENTION

[0009] An embodiment of t~~T~~he invention ~~which is described in claims 1 and 13 i~~is based on the problem of allowing rapid production of blind bores or through-holes during the laser drilling of laminates which have at least one metal layer and at least one dielectric layer comprising an organic material without the laminates being damaged.

[0010] An embodiment of t~~T~~he invention is based on the discovery

that frequency-doubled Nd vanadate lasers with a wavelength of 532 nm at short pulse widths of less than 40 ns can be used to effectively process both the metal layers and the dielectric layers.

[0011] In one~~this~~ case, pulse frequencies of ≥ 30 kHz can be~~are~~ selected for the laser drilling of the metal layers, while pulse frequencies of ≥ 20 kHz can be~~are~~ selected for the laser drilling of the dielectric layers. The selection of relatively high pulse frequencies for the processing of the organic materials results in particularly effective laser processing of both types of material. The laser processing of the organic materials results in a combination of photochemical and thermal decomposition which, compared to UV lasers, allows shorter processing times to be achieved and, compared to CO_2 lasers, avoids excessively high thermal loads.

[0012] The frequency-doubled Nd vanadate laser which is selected according to an embodiment of the invention for the drilling of laminates allows very high pulse frequencies, which may even be over 100 kHz, at low pulse widths of less than 40 ns. The high pulse frequencies allow rapid and effective processing of the laminates, while the low pulse widths ensure that the thermal load is very low. This combinastion of high pulse frequencies and short pulse widths cannot be achieved with other lasers which operate with similar or identical wavelengths. For example, in the case of the SHG YAG laser which is known from DE-A-198 24 225, at relatively high pulse frequencies it is at best possible to achieve pulse widths of 70 to 80 ns.

~~Advantageous configurations of the method according to the invention will emerge from claims 2 to 12.~~

[0013] One~~The~~ configuration ~~described in claim 2~~, through the use of pulse widths of less than 30 ns, allows the thermal load on the laminates during laser drilling to be reduced still further.

[0014] When using a focused laser beam with a spot diameter of between 10 μm and 100 μm ~~in accordance with claim 3~~, the laser processing of metal and organic material is effective. When using spot diameters of between 20 μm and 50 μm ~~in accordance with claim 4~~ the laser processing of the two materials can be

made even more effective.

[0015] On account of the higher absorption of the laser beams in the organic material, onethe configuration~~ described in claim 5~~ allows the processing rate to be increased considerably. The additives should have a significantly higher absorptance for laser beams with a wavelength of 532 nm than the pure organic material.

[0016] One~~The~~ refinement~~ described in claim 6~~ allows a particularly simple and economic increase in the absorptance of the organic material to be achieved.

[0017] One~~The~~ configuration~~ described in claim 7~~, on account of the choice of red additives, allows the absorptance to be optimized, since the green light of wavelength 532 nm is absorbed particularly well by the complementary color red.

[0018] One~~The~~ refinement ~~described in claim 8~~ provides, for the admixing of pigments as additive, a quantitative range which has proven particularly successful at increasing the absorptance without impairing the other properties. A~~The~~ narrower quantitative range ~~given in claim 9 is to~~can be regarded as optimal.

[0019] If the absorptance of the organic material is increased to at least 50% by the admixing of additives~~ in accordance with claim 10~~, the processing rate in the organic material has already been increased considerably. If the absorptance is increased to at least 60%, ~~in accordance with claim 11,~~ or to at least 80%~~, in accordance with claim 12~~, the processing times for the laser drilling of the organic material can be reduced further to a corresponding degree.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] The following types of laser were used in the examples described below:

[0021] Laser I:

Diode-pumped, frequency-doubled Nd vanadate laser produced by Spectra Physics, Mountain View, California, US.

Designation:	T80-YHP40-532QW
Wavelength:	532 nm
Power:	approx. 8.5 W
Operating mode:	Monomode TEMoo

Pulse width: 20 ns at pulse frequency 10 kHz
Pulse frequency: up to 200 kHz
Field size: 100 x 100 mm^2.

[0022] Laser II:
Diode-pumped, frequency-doubled Nd vanadate laser produced by Haas-Laser GmbH, Schramberg, DE.

Designation: None, since it is a prototype
Wavelength: 532 nm
Power: approx. 4.0 W
Operating mode: Monomode TEMoo
Pulse width: 25 ns at pulse frequency 10 kHz
Pulse frequency: up to 200 kHz
Field size: 100 x 100 mm^2.

[0023] The following materials were processed using lasers I and II:

[0024] Material I:
An RCC material (RCC = Resin Coated Copper Foil) is laminated onto a glass fiber-reinforced FR4 material (FR4 = level 4 fire retardant epoxy-glass composition) which was coated on both sides with copper foil. The result is a layer sequence comprising a 12 μm thick copper foil, a 60 μm thick layer of unreinforced epoxy material, a 16 μm thick copper foil, a 1 mm thick layer of glass fiber-reinforced epoxy material and a 16 μm thick copper foil.

[0025] Material II:
12 μm thick copper foils were laminated onto both sides of a 60 μm thick FR4 material.

[0026] The following additives were available to modify the materials I and II described above:

[0027] Additive I:
Organic red pigment bearing the designation "1501 Fast Red" (C.I. Pigment Red 48:1) produced by Xijinming Shenzhou City, Hebei Province, P.R. China. This is an azo pigment based on a barium salt.

[0028] Additive II:
Inorganic red pigment known as "Bayferrox™" (C.I. Pigment Red 101) produced by Bayer AG, DE. This is an iron oxide red pigment.

[0029] Additive III:
Polymer-soluble anthraquinone dye known as "Oracet™ Yellow GHS" (C.I. Solvent Yellow 163) produced by CIBA-Geigy AG, CH.

[0030] Additive IV:
Fibers of a ruby glass which has been produced by adding 2% by weight of selenium, 1% by weight of cadmium sulfide, 1% by weight of arsenic trioxide and 0.5% by weight of carbon to a base glass of the composition Na_2O-ZnO-$4SiO_2$.

[0031] Example 1:
The laser I was used to introduce blind bores with a diameter of 125 μm into the upper, 12 μm thick copper foil and the 60 μm thick dielectric layer comprising unreinforced epoxy material of the material I. The pulse frequency was 45 kHz for the drilling of the copper layer and 25 kHz for the drilling of the dielectric layer. The pulse length was 30 ns.

[0032] Using two galvanometer mirrors to divert the laser beam in the x-direction and in the y-direction, an area of 10 cm x 10 cm was processed. With a spot diameter of the focused laser beam of approx. 25 μm, the laser beam was moved in a small number of concentric circles in the outer region of the hole in order to drill through copper, the inner region of the copper foil then being expelled automatically. The diameter of the outer concentric circle was 110 μm. The linear velocity of the laser beam was 900 mm/s. To drill the epoxy material, the laser beam was set at 1.6 mm out of focus (OOF), but in this case too concentric circles were described. After the epoxy material had been drilled through, the copper foil below it was only slightly attacked.

[0033] The drilling of the copper foil took place at a rate of 289 holes per second, while the drilling of the epoxy material took place at a rate of 220 holes per second. The introduction of the blind bores into the laminate therefore took place at a speed of 120 holes per second.

[0034] Example 2:

The difference from Example 1 was that the laser II with the same laser parameters was used. In this case, the drilling of the copper foil took place at a rate of 145 holes per second, while the drilling of the epoxy material took place at a rate of 122 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 65 holes per second.

[0035] Example 3:

The difference from Example 1 was that the blind bores were introduced into the material II. The results were similar.

[0036] Example 4:

The difference from Example 2 was that the blind bores were introduced into the material II. The results were similar.

[0037] Example 5:

The difference from Example 1 was that blind bores with a diameter of 100 μm were produced. The copper foil was drilled at a rate of 398 holes per second, while the epoxy material was drilled at a rate of 382 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 183 holes per second.

[0038] Example 6:

The difference from Example 2 was that blind bores with a diameter of 100 μm were produced. The copper foil was drilled at a rate of 199 holes per second, while the epoxy material was drilled at a rate of 212 holes per second. Therefore, the introduction of the blind bores into the laminate took place at a rate of 99 holes per second.

[0039] Example 7:

The difference from Example 1 was that blind bores with a diameter of 75 μm were produced. The copper foil was drilled at a rate of 750 holes per second, while the epoxy material was drilled at a rate of 800 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 300 holes per second.

[0040] Example 8:

The difference from Example 2 was that blind bores with a diameter of 75 μm were produced. The copper foil was drilled at a rate of 370 holes per second, while the epoxy material was drilled at a rate of 400 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 150 holes per second.

[0041] Example 9:

The difference from Example 1 was that a modified material I, in which approx. 1.5% by weight of the additive I was admixed with the unreinforced epoxy material, was used. The improved absorption of the laser radiation enabled the rate at which the epoxy material was drilled to be increased to 550 holes per second. It was possible to increase the rate of introduction of the blind bores into the laminate by approx. 50%, to approximately 180 holes.

[0042] Example 10:

The difference from Example 9 was that approx. 1.5% by weight of the additive II was admixed with the unreinforced epoxy material. The results were similar.

[0043] Example 11:

The difference from Example 9 was that approx. 1.5% by weight of the additive III was admixed with the unreinforced epoxy material. The increase in the rate at which the epoxy material was drilled was in this case slightly lower.

[0044] Example 12:

The difference from Example 9 was that the laser II with the same laser parameters was used. It was possible to increase the rate at which the epoxy material was drilled to 306 holes per second.

[0045] Example 13:

The difference from Example 9 was that blind bores with a diameter of 100 μm were produced. The rate at which the epoxy material was drilled was 956 holes per second.

[0046] Example 14:

The difference from Example 12 was that blind bores with a diameter of 100 μm were produced. The rate at which the epoxy material was drilled was 531 holes per second.

[0047] Example 15:

The difference from Example 3 was that a modified material II was used, in which the FR4 material which, instead of the standard glass fiber reinforcement was reinforced with approx. 50% by weight of fibers of the additive IV, was formed as the epoxy material. It was possible to increase the rate at which this epoxy material was drilled by a factor of between 2 and 2.5.

[0048] Naturally, it is also possible to produce through-holes instead of the blind bores described in Examples 1 to 15. In this case, the lower copper foil is drilled under the same conditions and over the course of the same time as for the drilling of the upper copper foil.

[0049] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

W~~Patent Claims~~
hat is claimed is:

1. (Amended) A method for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer including~~comprising~~ an organic material, comprising:

~~characterized by the~~ useing ~~of~~ a frequency-doubled Nd vanadate laser having the following laser parameters~~:~~,

~~- P~~pulse width < 40 ns,

~~- P~~pulse frequency ≥ 30 kHz for the metal layer and ≥ 20 kHz for the dielectric layer, and

~~- W~~wavelength = 532 nm.

2. (Amended) The method as claimed in claim 1, wherein~~characterized in that~~ a pulse width of < 30 ns is used.

3. (Amended) The method as claimed in claim 1~~ or 2~~, wherein ~~characterized in that~~ a focused laser beam with a spot diameter of between 10 μm and 100 μm is used.

4. (Amended) The method as claimed in claim 3, wherein~~characterized in that~~ a focused laser beam with a spot diameter of between 20 μm and 40 μm is used.

5. (Amended) The method as claimed in claim 1~~one of the preceding claims~~, wherein~~ characterized in that~~ additives which have good absorptance for laser beams with a wavelength of 532 nm are admixed with the organic material.

6. (Amended) The method as claimed in claim 5, wherein~~characterized in that~~ at least one of an~~one~~ inorganic and~~/or~~ an organic pigment, ~~and/or a~~at least one polymer-soluble dye and~~/or~~ —at least one fibrous filler is used as additive.

7. (Amended) The method as claimed in claim 6, wherein ~~characterized in that~~ at least one of an~~one~~ inorganic red pigment and~~/or~~ an organic red pigment, and~~/or~~ a polymer-soluble red dye is used as additive.

8. (Amended) The method as claimed in claim 6~~ or 7~~, wherein~~characterized in that~~ between 0.1% by weight and 50% by weight of pigments are admixed with the organic material.

9. (Amended) The method as claimed in claim 6~~ or 7~~, wherein~~characterized in that~~ between 1% by weight and 2% by weight of pigments are admixed with the organic material.

10. (Amended) The method as claimed in ~~one of claims~~ 5~~ to 9~~, wherein~~ characterized in that~~ the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

11. (Amended) The method as claimed in ~~one of~~ claim~~s~~ 5~~ to 9~~, wherein~~characterized in that~~ the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

12. (Amended) The method as claimed in ~~one of~~ claim~~s~~ 5~~ to 9~~, wherein~~ characterized in that~~ the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

13. (Amended) A device for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer comprising an organic material, comprising: ~~using~~ a frequency-doubled Nd vanadate laser having the following laser parameters~~:~~,

~~—P~~pulse width	< 40 ns,
~~—P~~pulse frequency	≥ 30 kHz for the metal layer and
	≥ 20 kHz for the dielectric layer,
and	
~~—W~~wavelength	= 532 nm.

New claims

14. The method as claimed in claim 2, wherein a focused laser beam with a spot diameter of between 10 μm and 100 μm is used.

15. The method as claimed in claim 3, wherein a focused laser beam with a spot diameter of between 20 μm and 40 μm is used.

16. The method as claimed in claim 7, wherein between 0.1% by weight and 50% by weight of pigments are admixed with the organic material.

17. The method as claimed in 6, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

18. The method as claimed in 7, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

19. The method as claimed in 8, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

20. The method as claimed in 9, wherein the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

21. The method as claimed in claim 6, wherein the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

22. The method as claimed in claim 7, wherein the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

23. The method as claimed in claim 8, wherein the organic

material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

24. The method as claimed in claim 9, wherein the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

25. The method as claimed in claim 6, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

26. The method as claimed in claim 7, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

27. The method as claimed in claim 8, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

28. The method as claimed in claim 9, wherein the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

Abstract

A ~~M~~method and device for the laser drilling of laminates includes the use of

~~A~~a frequency-doubled Nd vanadate laser. The laser includes ~~having~~ the following parameters:

~~P~~ pulse width < 40 ns,

~~P~~pulse frequency ≥ 30 kHz for the metal layer and

≥ 20 kHz for the dielectric layer, and

~~W~~wavelength = 532 nm. Such a laser is

~~is~~ used for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer including~~comprising~~ an organic material.

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SUBSTITUTE SPECIFICATION

METHOD AND DEVICE FOR LASER DRILLING LAMINATES

[0001] This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/DE00/03424 which has an International filing date of September 29, 2000, which designated the United States of America, the entire contents of which are hereby incorporated by reference.

Field of the Invention

[0002] The invention generally relates to laser drilling.

Background of the Invention

[0003] It is known from EP-A-0 164 564 to produce blind bores in a laminate comprising the layer sequence metal-dielectric-metal with the aid of an excimer laser. The top metal layer of the laminate is in this case used as a perforated mask, the pattern of perforations in which is transferred photographically and is produced by subsequent etching. The dielectric which is uncovered in the region of the hole of this mask is then removed by the action of the excimer laser until the bottom metal layer is reached and the process of removing material is terminated. The known method is used in particular to produce the required through-contact holes in the form of blind bores during the fabrication of multilayer circuit boards.

[0004] German journal "Feinwerktechnik & Messtechnik 91 (1983) 2, pp. 56-58 has disclosed a similar method for the fabrication of multilayer circuit boards in which the blind bores which are used as through-contacts are produced with the aid of a CO_2 laser. In this case too, the top copper foil is used as a perforated mask, in which the copper is etched away wherever the laser beam is to produce a hole.

[0005] DE-A-197 19 700 has also already disclosed devices for the laser drilling of laminates in which a first laser, having a wavelength in the range from approximately 266 nm to 1064 nm, is used to drill the metal layers and a second laser, having a wavelength in the range from approximately 1064 nm to 10 600 nm, is used to drill the dielectric layers.

[0006] US-A-5 593 606 has disclosed a method for the laser drilling of laminates in which a single UV laser, the wavelengths of which are below 400 nm and the pulse widths of which are below 100 ns, is used to drill the metal layers and to drill the dielectric layers. Therefore, on the condition that an excimer laser is not used, metal and organic material are drilled using the same UV laser.

[0007] DE-A-198 24 225 has disclosed a further method for the laser drilling of laminates, in which, by way of example, an SHG (second harmonic generation) YAG laser with a wavelength of 532 nm or a THG (third harmonic generation) YAG laser with a wavelength of

355 nm can be used to drill the metal layers and to drill the dielectric layers.

[0008] It can fundamentally be stated that, when UV lasers, i.e. lasers with wavelengths of below 400 nm, are used for the laser drilling of organic materials, photochemical decomposition of the organic materials takes place. Therefore, there is no burning and, on account of the at most extremely low thermal load, there is no delamination when used for laminates. By contrast, when CO_2 lasers are used for the laser drilling of organic materials, thermal decomposition of the organic materials does occur, i.e. burning may occur and there is a risk of delamination in the case of laminates. However, compared to UV lasers, CO_2 lasers can achieve considerably shorter processing times when drilling organic materials.

SUMMARY OF THE INVENTION

[0009] An embodiment of the invention is based on the problem of allowing rapid production of blind bores or through-holes during the laser drilling of laminates which have at least one metal layer and at least one dielectric layer comprising an organic material without the laminates being damaged.

[0010] An embodiment of the invention is based on the discovery that frequency-doubled Nd vanadate lasers with a wavelength of 532 nm at short pulse widths of less than 40 ns can be used to effectively process both the metal layers and the dielectric layers.

[0011] In one case, pulse frequencies of ≥ 30 kHz can be selected for the laser drilling of the metal layers, while pulse frequencies of ≥ 20 kHz can be selected for the laser drilling of the dielectric layers. The selection of relatively high pulse frequencies for the processing of the organic materials results in particularly effective laser processing of both types of material. The laser processing of the organic materials results in a combination of photochemical and thermal decomposition which, compared to UV lasers, allows shorter processing times to be achieved and, compared to CO_2 lasers, avoids excessively high thermal loads.

[0012] The frequency-doubled Nd vanadate laser which is selected according to an embodiment of the invention for the drilling of laminates allows very high pulse frequencies, which may even be over 100 kHz, at low pulse widths of less than 40 ns. The high pulse frequencies allow rapid and effective processing of the laminates, while the low pulse widths ensure that the thermal load is very low. This combinastion of high pulse frequencies and short pulse widths cannot be achieved with other lasers which operate with similar or identical wavelengths. For example, in the case of the SHG YAG laser which is known from DE-A-198 24 225, at relatively high pulse frequencies it is at best possible to achieve pulse widths of 70 to 80 ns.

[0013] One configuration , through the use of pulse widths of less than 30 ns, allows the thermal load on the laminates during laser drilling to be reduced still further.

[0014] When using a focused laser beam with a spot diameter of between 10 μm and 100 μm,

the laser processing of metal and organic material is effective. When using spot diameters of between 20 μm and 50 μm the laser processing of the two materials can be made even more effective.

[0015] On account of the higher absorption of the laser beams in the organic material, one configuration allows the processing rate to be increased considerably. The additives should have a significantly higher absorptance for laser beams with a wavelength of 532 nm than the pure organic material.

[0016] One refinement allows a particularly simple and economic increase in the absorptance of the organic material to be achieved.

[0017] One configuration, on account of the choice of red additives, allows the absorptance to be optimized, since the green light of wavelength 532 nm is absorbed particularly well by the complementary color red.

[0018] One refinement provides, for the admixing of pigments as additive, a quantitative range which has proven particularly successful at increasing the absorptance without impairing the other properties. A narrower quantitative range can be regarded as optimal.

[0019] If the absorptance of the organic material is increased to at least 50% by the admixing of additives, the processing rate in the organic material has already been increased considerably. If the absorptance is increased to at least 60%, or to at least 80%, the processing times for the laser drilling of the organic material can be reduced further to a corresponding degree.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] The following types of laser were used in the examples described below:

[0021] Laser I:

Diode-pumped, frequency-doubled Nd vanadate laser produced by Spectra Physics, Mountain View, California, US.

Designation:	T80-YHP40-532QW
Wavelength:	532 nm
Power:	approx. 8.5 W
Operating mode:	Monomode TEMoo
Pulse width:	20 ns at pulse frequency 10 kHz
Pulse frequency:	up to 200 kHz
Field size:	100 x 100 mm^2.

[0022] Laser II:

Diode-pumped, frequency-doubled Nd vanadate laser produced by Haas-Laser GmbH, Schramberg, DE.

Designation:	None, since it is a prototype

Wavelength:	532 nm
Power:	approx. 4.0 W
Operating mode:	Monomode TEMoo
Pulse width:	25 ns at pulse frequency 10 kHz
Pulse frequency:	up to 200 kHz
Field size:	100 x 100 mm^2.

[0023] The following materials were processed using lasers I and II:

[0024] Material I:
An RCC material (RCC = Resin Coated Copper Foil) is laminated onto a glass fiber-reinforced FR4 material (FR4 = level 4 fire retardant epoxy-glass composition) which was coated on both sides with copper foil. The result is a layer sequence comprising a 12 μm thick copper foil, a 60 μm thick layer of unreinforced epoxy material, a 16 μm thick copper foil, a 1 mm thick layer of glass fiber-reinforced epoxy material and a 16 μm thick copper foil.

[0025] Material II:
12 μm thick copper foils were laminated onto both sides of a 60 μm thick FR4 material.

[0026] The following additives were available to modify the materials I and II described above:

[0027] Additive I:
Organic red pigment bearing the designation "1501 Fast Red" (C.I. Pigment Red 48:1) produced by Xijinming Shenzhou City, Hebei Province, P.R. China. This is an azo pigment based on a barium salt.

[0028] Additive II:
Inorganic red pigment known as "Bayferrox™" (C.I. Pigment Red 101) produced by Bayer AG, DE. This is an iron oxide red pigment.

[0029] Additive III:
Polymer-soluble anthraquinone dye known as "Oracet™ Yellow GHS" (C.I. Solvent Yellow 163) produced by CIBA-Geigy AG, CH.

[0030] Additive IV:

Fibers of a ruby glass which has been produced by adding 2% by weight of selenium, 1% by weight of cadmium sulfide, 1% by weight of arsenic trioxide and 0.5% by weight of carbon to a base glass of the composition Na_2O-ZnO-$4SiO_2$.

[0031] Example 1:

The laser I was used to introduce blind bores with a diameter of 125 μm into the upper, 12 μm thick copper foil and the 60 μm thick dielectric layer comprising unreinforced epoxy material of the material I. The pulse frequency was 45 kHz for the drilling of the copper layer and 25 kHz for the drilling of the dielectric layer. The pulse length was 30 ns.

[0032] Using two galvanometer mirrors to divert the laser beam in the x-direction and in the y-direction, an area of 10 cm x 10 cm was processed. With a spot diameter of the focused laser beam of approx. 25 μm, the laser beam was moved in a small number of concentric circles in the outer region of the hole in order to drill through copper, the inner region of the copper foil then being expelled automatically. The diameter of the outer concentric circle was 110 μm. The linear velocity of the laser beam was 900 mm/s. To drill the epoxy material, the laser beam was set at 1.6 mm out of focus (OOF), but in this case too concentric circles were described. After the epoxy material had been drilled through, the copper foil below it was only slightly attacked.

[0033] The drilling of the copper foil took place at a rate of 289 holes per second, while the drilling of the epoxy material took place at a rate of 220 holes per second. The introduction of the blind bores into the laminate therefore took place at a speed of 120 holes per second.

[0034] Example 2:

The difference from Example 1 was that the laser II with the same laser parameters was used. In this case, the drilling of the copper foil took place at a rate of 145 holes per second, while the drilling of the epoxy material took place at a rate of 122 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 65 holes per second.

[0035] Example 3:

The difference from Example 1 was that the blind bores were introduced into the material II. The results were similar.

[0036] Example 4:

The difference from Example 2 was that the blind bores were introduced into the material II. The results were similar.

[0037] Example 5:

The difference from Example 1 was that blind bores with a diameter of 100 μm were

produced. The copper foil was drilled at a rate of 398 holes per second, while the epoxy material was drilled at a rate of 382 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 183 holes per second.

[0038] Example 6:

The difference from Example 2 was that blind bores with a diameter of 100 μm were produced. The copper foil was drilled at a rate of 199 holes per second, while the epoxy material was drilled at a rate of 212 holes per second. Therefore, the introduction of the blind bores into the laminate took place at a rate of 99 holes per second.

[0039] Example 7:

The difference from Example 1 was that blind bores with a diameter of 75 μm were produced. The copper foil was drilled at a rate of 750 holes per second, while the epoxy material was drilled at a rate of 800 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 300 holes per second.

[0040] Example 8:

The difference from Example 2 was that blind bores with a diameter of 75 μm were produced. The copper foil was drilled at a rate of 370 holes per second, while the epoxy material was drilled at a rate of 400 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 150 holes per second.

[0041] Example 9:

The difference from Example 1 was that a modified material I, in which approx. 1.5% by weight of the additive I was admixed with the unreinforced epoxy material, was used. The improved absorption of the laser radiation enabled the rate at which the epoxy material was drilled to be increased to 550 holes per second. It was possible to increase the rate of introduction of the blind bores into the laminate by approx. 50%, to approximately 180 holes.

[0042] Example 10:

The difference from Example 9 was that approx. 1.5% by weight of the additive II was admixed with the unreinforced epoxy material. The results were similar.

[0043] Example 11:

The difference from Example 9 was that approx. 1.5% by weight of the additive III was admixed with the unreinforced epoxy material. The increase in the rate at which the epoxy

material was drilled was in this case slightly lower.

[0044] Example 12:

The difference from Example 9 was that the laser II with the same laser parameters was used. It was possible to increase the rate at which the epoxy material was drilled to 306 holes per second.

[0045] Example 13:

The difference from Example 9 was that blind bores with a diameter of 100 μm were produced. The rate at which the epoxy material was drilled was 956 holes per second.

[0046] Example 14:

The difference from Example 12 was that blind bores with a diameter of 100 μm were produced. The rate at which the epoxy material was drilled was 531 holes per second.

[0047] Example 15:

The difference from Example 3 was that a modified material II was used, in which the FR4 material which, instead of the standard glass fiber reinforcement was reinforced with approx. 50% by weight of fibers of the additive IV, was formed as the epoxy material. It was possible to increase the rate at which this epoxy material was drilled by a factor of between 2 and 2.5.

[0048] Naturally, it is also possible to produce through-holes instead of the blind bores described in Examples 1 to 15. In this case, the lower copper foil is drilled under the same conditions and over the course of the same time as for the drilling of the upper copper foil.

[0049] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

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New Foreign Version

Description

Method and device for the laser drilling of laminates

It is known from EP-A-0 164 564 to produce blind bores in a laminate comprising the layer sequence metal-dielectric-metal with the aid of an excimer laser. The top metal layer of the laminate is in this case used as a perforated mask, the pattern of perforations in which is transferred photographically and is produced by subsequent etching. The dielectric which is uncovered in the region of the hole of this mask is then removed by the action of the excimer laser until the bottom metal layer is reached and the process of removing material is terminated. The known method is used in particular to produce the required through-contact holes in the form of blind bores during the fabrication of multilayer circuit boards.

German journal "Feinwerktechnik & Messtechnik 91 (1983) 2, pp. 56-58 has disclosed a similar method for the fabrication of multilayer circuit boards in which the blind bores which are used as through-contacts are produced with the aid of a CO_2 laser. In this case too, the top copper foil is used as a perforated mask, in which the copper is etched away wherever the laser beam is to produce a hole.

DE-A-197 19 700 has also already disclosed devices for the laser drilling of laminates in which a first laser, having a wavelength in the range from approximately 266 nm to 1064 nm, is used to drill the metal layers and a second laser, having a wavelength in the range from approximately 1064 nm to 10 600 nm, is used to drill the dielectric layers.

US-A-5 593 606 has disclosed a method for the

laser drilling of laminates in which a single UV laser, the wavelengths of which are below 400 nm and the pulse widths of which are below 100 ns, is used to drill the metal layers and to drill the dielectric layers. Therefore,

on the condition that an excimer laser is not used, metal and organic material are drilled using the same UV laser.

DE-A-198 24 225 has disclosed a further method for the laser drilling of laminates, in which, by way of example, an SHG (second harmonic generation) YAG laser with a wavelength of 532 nm or a THG (third harmonic generation) YAG laser with a wavelength of 355 nm can be used to drill the metal layers and to drill the dielectric layers.

It can fundamentally be stated that, when UV lasers, i.e. lasers with wavelengths of below 400 nm, are used for the laser drilling of organic materials, photochemical decomposition of the organic materials takes place. Therefore, there is no burning and, on account of the at most extremely low thermal load, there is no delamination when used for laminates. By contrast, when CO_2 lasers are used for the laser drilling of organic materials, thermal decomposition of the organic materials does occur, i.e. burning may occur and there is a risk of delamination in the case of laminates. However, compared to UV lasers, CO_2 lasers can achieve considerably shorter processing times when drilling organic materials.

The invention which is described in claims 1 and 13 is based on the problem of allowing rapid production of blind bores or through-holes during the laser drilling of laminates which have at least one metal layer and at least one dielectric layer comprising an organic material without the laminates being damaged.

The invention is based on the discovery that frequency-doubled Nd vanadate lasers with a wavelength of 532 nm at short pulse widths of less than 40 ns can be used to effectively process both the metal layers

and the dielectric layers.

In this case, pulse frequencies of ≥ 30 kHz are selected for the laser drilling of the metal layers, while pulse frequencies of ≥ 20 kHz are selected for the laser drilling of the dielectric layers. The selection of relatively high pulse frequencies for the processing of the organic materials results in particularly effective laser processing of both types of material. The laser processing of the organic materials results in a combination of photochemical and thermal decomposition which, compared to UV lasers, allows shorter processing times to be achieved and, compared to CO_2 lasers, avoids excessively high thermal loads.

The frequency-doubled Nd vanadate laser which is selected according to the invention for the drilling of laminates allows very high pulse frequencies, which may even be over 100 kHz, at low pulse widths of less than 40 ns. The high pulse frequencies allow rapid and effective processing of the laminates, while the low pulse widths ensure that the thermal load is very low. This combinastion of high pulse frequencies and short pulse widths cannot be achieved with other lasers which operate with similar or identical wavelengths. For example, in the case of the SHG YAG laser which is known from DE-A-198 24 225, at relatively high pulse frequencies it is at best possible to achieve pulse widths of 70 to 80 ns.

Advantageous configurations of the method according to the invention will emerge from claims 2 to 12.

The configuration described in claim 2, through the use of pulse widths of less than 30 ns, allows the thermal load on the laminates during laser drilling to be reduced still further.

When using a focused laser beam with a spot diameter of between 10 μm and 100 μm in accordance with claim 3, the laser processing of metal and organic material is effective. When using spot diameters

of between 20 μm and 50 μm in accordance with claim 4 the laser processing of the two materials can be made even more effective.

On account of the higher absorption of the laser beams in the organic material, the configuration described in claim 5 allows the processing rate to be increased considerably. The additives should have a significantly higher absorptance for laser beams with a wavelength of 532 nm than the pure organic material.

The refinement described in claim 6 allows a particularly simple and economic increase in the absorptance of the organic material to be achieved.

The configuration described in claim 7, on account of the choice of red additives, allows the absorptance to be optimized, since the green light of wavelength 532 nm is absorbed particularly well by the complementary color red.

The refinement described in claim 8 provides, for the admixing of pigments as additive, a quantitative range which has proven particularly successful at increasing the absorptance without impairing the other properties. The narrower quantitative range given in claim 9 is to be regarded as optimal.

If the absorptance of the organic material is increased to at least 50% by the admixing of additives in accordance with claim 10, the processing rate in the organic material has already been increased considerably. If the absorptance is increased to at least 60%, in accordance with claim 11, or to at least 80%, in accordance with claim 12, the processing times for the laser drilling of the organic material can be reduced further to a corresponding degree.

The following types of laser were used in the examples described below:

Laser I:

Diode-pumped, frequency-doubled Nd vanadate laser produced by Spectra Physics, Mountain View, California, US.

Designation:	T80-YHP40-532QW
Wavelength:	532 nm
Power:	approx. 8.5 W
Operating mode:	Monomode TEMoo
Pulse width:	20 ns at pulse frequency 10 kHz
Pulse frequency:	up to 200 kHz
Field size:	100 x 100 mm^2.

Laser II:

Diode-pumped, frequency-doubled Nd vanadate laser produced by Haas-Laser GmbH, Schramberg, DE.

Designation:	None, since it is a prototype
Wavelength:	532 nm
Power:	approx. 4.0 W
Operating mode:	Monomode TEMoo
Pulse width:	25 ns at pulse frequency 10 kHz
Pulse frequency:	up to 200 kHz
Field size:	100 x 100 mm^2.

The following materials were processed using lasers I and II:

Material I:

An RCC material (RCC = Resin Coated Copper Foil) is laminated onto a glass fiber-reinforced FR4 material (FR4 = level 4 fire retardant epoxy-glass composition) which was coated on both sides with copper foil. The result is a layer sequence comprising a 12 μm thick

copper foil, a 60 μm thick layer of unreinforced epoxy material, a 16 μm thick copper foil, a 1 mm thick layer of glass fiber-

reinforced epoxy material and a 16 μm thick copper foil.

Material II:

12 μm thick copper foils were laminated onto both sides of a 60 μm thick FR4 material.

The following additives were available to modify the materials I and II described above:

Additive I:

Organic red pigment bearing the designation "1501 Fast Red" (C.I. Pigment Red 48:1) produced by Xijinming Shenzhou City, Hebei Province, P.R. China. This is an azo pigment based on a barium salt.

Additive II:

Inorganic red pigment known as "Bayferrox™" (C.I. Pigment Red 101) produced by Bayer AG, DE. This is an iron oxide red pigment.

Additive III:

Polymer-soluble anthraquinone dye known as "Oracet™ Yellow GHS" (C.I. Solvent Yellow 163) produced by CIBA-Geigy AG, CH.

Additive IV:

Fibers of a ruby glass which has been produced by adding 2% by weight of selenium, 1% by weight of cadmium sulfide, 1% by weight of arsenic trioxide and 0.5% by weight of carbon to a base glass of the composition Na_2O-ZnO-$4SiO_2$.

Example 1:

The laser I was used to introduce blind bores with a diameter of 125 μm into the upper, 12 μm thick copper foil and the 60 μm thick dielectric layer comprising unreinforced epoxy material of the material I. The

pulse frequency was 45 kHz for the drilling of the copper layer and 25 kHz for the drilling of the dielectric layer. The pulse length was 30 ns.

Using two galvanometer mirrors to divert the laser beam in the x-direction and in the y-direction, an area of 10 cm x 10 cm was processed. With a spot diameter of the focused laser beam of approx. 25 μm, the laser beam was moved in a small number of concentric circles in the outer region of the hole in order to drill through copper, the inner region of the copper foil then being expelled automatically. The diameter of the outer concentric circle was 110 μm. The linear velocity of the laser beam was 900 mm/s. To drill the epoxy material, the laser beam was set at 1.6 mm out of focus (OOF), but in this case too concentric circles were described. After the epoxy material had been drilled through, the copper foil below it was only slightly attacked.

The drilling of the copper foil took place at a rate of 289 holes per second, while the drilling of the epoxy material took place at a rate of 220 holes per second. The introduction of the blind bores into the laminate therefore took place at a speed of 120 holes per second.

Example 2:

The difference from Example 1 was that the laser II with the same laser parameters was used. In this case, the drilling of the copper foil took place at a rate of 145 holes per second, while the drilling of the epoxy material took place at a rate of 122 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 65 holes per second.

Example 3:

The difference from Example 1 was that the blind bores were introduced into the material II. The results were similar.

Example 4:

The difference from Example 2 was that the blind bores were introduced into the material II. The results were similar.

Example 5:

The difference from Example 1 was that blind bores with a diameter of 100 μm were produced. The copper foil was drilled at a rate of 398 holes per second, while the epoxy material was drilled at a rate of 382 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 183 holes per second.

Example 6:

The difference from Example 2 was that blind bores with a diameter of 100 μm were produced. The copper foil was drilled at a rate of 199 holes per second, while the epoxy material was drilled at a rate of 212 holes per second. Therefore, the introduction of the blind bores into the laminate took place at a rate of 99 holes per second.

Example 7:

The difference from Example 1 was that blind bores with a diameter of 75 μm were produced. The copper foil was drilled at a rate of 750 holes per second, while the epoxy material was drilled at a rate of 800 holes per second. Therefore, the blind bores were introduced into the laminate at a rate of 300 holes per second.

Example 8:

The difference from Example 2 was that blind bores with a diameter of 75 μm were produced. The copper foil was drilled at a rate of 370 holes per second, while the epoxy material was drilled at a rate of 400 holes per second. Therefore, the

blind bores were introduced into the laminate at a rate of 150 holes per second.

Example 9:

The difference from Example 1 was that a modified material I, in which approx. 1.5% by weight of the additive I was admixed with the unreinforced epoxy material, was used. The improved absorption of the laser radiation enabled the rate at which the epoxy material was drilled to be increased to 550 holes per second. It was possible to increase the rate of introduction of the blind bores into the laminate by approx. 50%, to approximately 180 holes.

Example 10:

The difference from Example 9 was that approx. 1.5% by weight of the additive II was admixed with the unreinforced epoxy material. The results were similar.

Example 11:

The difference from Example 9 was that approx. 1.5% by weight of the additive III was admixed with the unreinforced epoxy material. The increase in the rate at which the epoxy material was drilled was in this case slightly lower.

Example 12:

The difference from Example 9 was that the laser II with the same laser parameters was used. It was possible to increase the rate at which the epoxy material was drilled to 306 holes per second.

Example 13:

The difference from Example 9 was that blind bores with a diameter of 100 μm were produced. The rate at which the epoxy material was drilled was 956 holes per second.

Example 14:

The difference from Example 12 was that blind bores with a diameter of 100 μm were produced. The rate at which the epoxy material was drilled was 531 holes per second.

Example 15:

The difference from Example 3 was that a modified material II was used, in which the FR4 material which, instead of the standard glass fiber reinforcement was reinforced with approx. 50% by weight of fibers of the additive IV, was formed as the epoxy material. It was possible to increase the rate at which this epoxy material was drilled by a factor of between 2 and 2.5.

Naturally, it is also possible to produce through-holes instead of the blind bores described in Examples 1 to 15. In this case, the lower copper foil is drilled under the same conditions and over the course of the same time as for the drilling of the upper copper foil.

Patent Claims

1. A method for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer comprising an organic material, characterized by the use of a frequency-doubled Nd vanadate laser having the following laser parameters:

- Pulse width	< 40 ns
- Pulse frequency	≥ 30 kHz for the metal layer
	≥ 20 kHz for the dielectric layer
- Wavelength	= 532 nm.

2. The method as claimed in claim 1, characterized in that a pulse width of < 30 ns is used.

3. The method as claimed in claim 1 or 2, characterized in that a focused laser beam with a spot diameter of between 10 μm and 100 μm is used.

4. The method as claimed in claim 3, characterized in that a focused laser beam with a spot diameter of between 20 μm and 40 μm is used.

5. The method as claimed in one of the preceding claims, characterized in that additives which have good absorptance for laser beams with a wavelength of 532 nm are admixed with the organic material.

6. The method as claimed in claim 5, characterized in that at least one inorganic and/or organic pigment and/or at least one polymer-soluble dye and/or at least one fibrous filler is used as additive.

7. The method as claimed in claim 6, characterized in that at least one inorganic red

pigment and/or an organic red pigment and/or a polymer-soluble red dye is used as additive.

8. The method as claimed in claim 6 or 7, characterized in that between 0.1% by weight and 50% by weight of pigments are admixed with the organic material.

9. The method as claimed in claim 6 or 7, characterized in that between 1% by weight and 2% by weight of pigments are admixed with the organic material.

10. The method as claimed in one of claims 5 to 9, characterized in that the organic material, on account of the admixed additives, has an absorptance of at least 50% for the wavelength 532 nm of the laser radiation.

11. The method as claimed in one of claims 5 to 9, characterized in that the organic material, on account of the admixed additives, has an absorptance of at least 60% for the wavelength 532 nm of the laser radiation.

12. The method as claimed in one of claims 5 to 9, characterized in that the organic material, on account of the admixed additives, has an absorptance of at least 80% for the wavelength 532 nm of the laser radiation.

13. A device for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer comprising an organic material, using a frequency-doubled Nd vanadate laser having the following laser parameters:

- Pulse width < 40 ns

- Pulse frequency $\geq$ 30 kHz for the metal layer
  $\geq$ 20 kHz for the dielectric layer
- Wavelength = 532 nm.

10/089301

Abstract

Method and device for the laser drilling of laminates

A frequency-doubled Nd vanadate laser having the following parameters:

- Pulse width	< 40 ns
- Pulse frequency	≥ 30 kHz for the metal layer
	≥ 20 kHz for the dielectric layer
- Wavelength	= 532 nm

is used for the laser drilling of laminates which have at least one metal layer and at least one dielectric layer comprising an organic material.

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

VERFAHREN UND EINRICHTEN ZUM LASERBOHREN VON LAMINATEN

METHOD AND DEVICE FOR LASER DRILLING LAMINATES

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 29.09.2000 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/DE00/03424
eingereicht wurde und am _______
abgeändert wurde (falls tatsächlich abgeändert).

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 29.09.2000 as
PCT international application
PCT Application No. PCT/DE00/03424
and was amended on __________
(if applicable)

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

German Language Declaration

Prior foreign appplications
Prioritát beansprucht

Priority Claimed

19947027.8	DE	30.09.1999	☒ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
			☐ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
			☐ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE00/03424	29.09.2000	anhängig	pending
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D, M, Y) (Anmeldedatum T, M, J)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

German Language Declaration

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

And I hereby appoint

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1-00

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3-00

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Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address
Voller Name des sechsten Miterfinders:	Full name of sixth joint inventor:
Unterschrift des Erfinders Datum	Inventor's signature Date
Wohnsitz ,	Residence ,
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